POWER AMPLIFIER (PA) WITH IMPROVED POWER REGULATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is generally related to power amplifiers, and, more specifically, to a system and method for regulating the power produced by a power amplifier.

2. Discussion of the Background

In certain communication systems, for example, the Global System for Mobile Communication (GSM), the output power of a transmitter within a communication device (e.g., a mobile phone) has to be well controlled due to the specifications of the communication system. In transmitters used in GSM and GSM like systems, the output power of the transmitter is generated by a power amplifier, which is controlled by a control circuit.

The output power (P) of a power amplifier is a function of load impedance (R), as shown by the following formula: $P = I^2R$, where I is the current provided to the load from the power amplifier. Thus, if the load impedance (R) changes, the output power (P) will change (assuming I is kept constant). Changes to the load impedance are commonly caused by environmental factors. For example, if the load is an antenna of a transmitter for transmitting signals, the load impedance is dependent upon the environment surrounding the antenna. As an example, if a mobile phone is held in the

hand, the impedance "felt" by the power amplifier may be different from the impedance felt by the power amplifier when the mobile phone is sitting on a table or in a car. Because the output power must be well controlled, it is desired to keep the output power constant, regardless of changes in the load impedance.

Conventionally, the output power has been controlled though the use of a current detector. FIG. 1 illustrates a conventional circuit for controlling the output power of a power amplifier 102. As shown in FIG. 1, the current (I_1) flowing into power amplifier 102 is measured. I_1 is a good measure of the power produced by power amplifier 102. This current is measured by measuring the voltage at node N1. This voltage is referred to as Vsense. By Ohm's law, Vsense is related to (I_1) as follows: Vsense = Vbat - (I_1)R1, where Vbat is the voltage produced by power source 110. L1 is an RF-choke inductor. A control circuit 108 compares Vsense to a reference voltage (Vref). Control circuit 108 controls the output power of power amplifier 102 based on the result of the comparison between Vsense and Vref. In this manner, the circuit shown in FIG. 1 may control the output power of power amplifier 102 based on the measured current (I_1) flowing into the power amplifier 102. The circuit shown in FIG. 1 suffers from several disadvantages, one of which is that it has difficulty achieving high dynamics.

What is desired, therefore, is a system and/or method to improve the power regulation of a power amplifier circuit.

SUMMARY OF THE INVENTION

Embodiments of the present invention provide a system and method for improving the power regulation of a power amplifier circuit. More specifically, the present invention improves control of output power in the situations where there is an impedance mismatch at the output.

According to one embodiment, a method of the present invention includes the steps of (1) comparing a measured signal to a reference signal, wherein the measured signal represents the sum of the amplitude of the output voltage of the power amplifier and a current flowing into the power amplifier from a power supply connected to the power amplifier and (2) controlling the power amplifier based on the result of the comparison between the measured signal and the reference signal.

According to one embodiment, a circuit of the present invention includes a current detector for measuring the current flowing into the power amplifier from a power supply, an amplitude detector that measures the amplitude of the output voltage of the power amplifier, an adder for summing the output of the current detector and the amplitude detector, and a control circuit connected to a biasing pin of the power amplifier that compares the output of the adder to a reference signal and controls the power amplifier based on the result of the comparison between the reference signal and the output of the adder.

The output of the adder changes as the impedance of the load on the power amplifier changes. Thus, because the output of the control circuit will change when the output of the adder changes, the output of the control circuit changes when the impedance of the load changes. Because the output of the control circuit is connected to

the biasing input of the power amplifier, the output of the control circuit controls the current delivered by the power amplifier to the load, and, hence, controls the power delivered to the load. When the impedance of the load changes, the control circuit increases or decreases the current delivered to the load, depending on the change in the impedance of the load. In this manner, the control circuit regulates the power delivered by the power amplifier to the load and can keep the output power constant, regardless of changes in the load.

Further features and advantages of the present invention, as well as the structure and operation of various embodiments of the present invention, are described in detail below with reference to the accompanying drawings.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps, or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated herein and form part of the specification, illustrate various embodiments of the present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the

left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

FIG. 1 illustrates a conventional circuit for controlling the output power of a power amplifier.

FIG. 2 is a high level circuit diagram illustrating an embodiment of the invention.

FIG. 3 depicts one possible implementation of the high level circuit shown in FIG. 2.

FIG. 4 is a schematic of one embodiment of an amplitude detector circuit.

FIG. 5 is a schematic of one embodiment of a voltage to current generator.

FIG. 6 is a flowchart illustrating a process, according to one embodiment of the invention, for controlling the output power of a power amplifier circuit.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring first to FIG. 6, FIG. 6 is a flow chart illustrating a process 600, according to one embodiment of the invention, for controlling the output power of a power amplifier circuit. Process 600 begins with step 602, wherein a measurement corresponding to a current flowing into the power amplifier from a power source is produced. In step 604, a measurement corresponding to the amplitude of an output signal produced by the power amplifier is produced. In step 606, the measurements from step 602 and 604 are added together. In step 608, the resulting sum is compared to a reference. In step 610, the power amplifier is controlled based on the result of the

comparison. In this manner, the method of the present invention regulates the output power of a power amplifier circuit.

Referring now to FIG. 2, FIG 2. illustrates a high level circuit diagram that illustrates a power amplifier circuit 200 according to one embodiment. Power amplifier circuit 200 includes power amplifier 102 that functions to receive an input signal at its input 104 and to amplify the input signal to produce an output signal at its output 106.

Circuit 200 also includes a control circuit 108 for controlling the output power of power amplifier 102. More specifically, control circuit 108 functions to keep the output power of power amplifier 102 constant, regardless of changes in the impedance of a load 105 connected to the output 106 of power amplifier 102. The output of control circuit 108 is connected to a biasing control pin 103 of power amplifier 102. Thus, the output of control circuit 108 affects the amount of current (I) provided to load 105.

Circuit 200 also includes power source 110 (Vbat) that provides power to power amplifier 102, a current detector 280 for measuing the current flowing out of power source 110, an amplitude detector 220 for measuring the amplitude of the output signal of power amplifier 102, and an adder 285 for adding the outputs of current detector 280 and amplitude detector 220. The output of adder 285 is provided to an input of control circuit 108. Provided to another input of control circuit 108 is the reference signal (Vref). Controller 108 controls power amplifier 102 based on the difference between the output of adder 285 and the reference signal.

In one embodiment, control circuit 108 is a comparator. That is, control circuit 108 compares the output of adder 285 to the reference signal and outputs a voltage that

corresponds to the difference between the two inputs. The output of adder 285 changes when the real part of the impedance of load 105 changes. Thus, because the output of control circuit 108 will change when the output of adder 285 changes, the output of control circuit 108 changes when the impedance of load 105 changes. As discussed above, the output of control circuit 108 affects the current (I) delivered by power amplifier 102 to load 105. Consequently, when the impedance of load 105 changes, control circuit 108 increases or decreases the current delivered to load 105, depending on the impedance of load 105. In this manner, control circuit 108 regulates the power delivered by power amplifier 102 to load 105 and can keep the output power constant, regardless of changes in the load.

FIG. 3 illustrates circuit 200 in greater detail according to one embodiment. One skilled in the art will recognize that there are a wide variety of ways to implement circuit 200 and that FIG. 3 is used merely for illustration and not limitation. As shown in FIG. 3, current detector 280 is implemented with a resistor (R1), adder 285 is implemented with a resistor (R2), and amplitude detector 220 is implemented with an envelope detector 320 and a voltage to current generator 322.

Detector circuit 320 functions to output a voltage that corresponds to the amplitude of the output signal produced by power amplifier 102. Voltage to current generator 322 receives as input the output of detector circuit 320. The output of generator 322 is connected to adder 285. Generator 322 converts the voltage outputted by circuit 320 to a current I_2. This current is drawn through resistors R1 and R2 (R2 is preferably greater than R1).

Referring now to FIG. 4, FIG. 4 is a schematic of one embodiment of detector circuit 320. As shown in FIG. 4, detector circuit 320 includes a diode 401 connected in series with a resistance (R3) connected in parallel with a capacitance (C1). The input to the detector circuit 320 is the output 106 of power amplifier 102. The output of detector circuit 320 is a voltage that corresponds to the amplitude of the output signal 106 of power amplifier 102. For this reason, detector circuit 320 is also referred to as an amplitude detector or envelope detector. One skilled in the art will recognize that there are a wide variety of ways to implement circuit 320 and that FIG. 4 is used merely for illustration and not limitation.

Referring now to FIG. 5, FIG. 5 is a schematic of one embodiment of voltage to current generator 322. As shown in FIG. 5, generator 322 includes a bi-polar junction transistor 502. The input of generator 322 is connected to the base 504 of transistor 502 through a resistance (R4). The base 504 is also connected to ground through a resistance (R5). The emitter 506 is connected to ground through a resistance (R6), and the collector 508 is the output terminal of generator 322. One skilled in the art will recognize that there are a wide variety of ways to implement generator 322 and that FIG. 5 is used merely for illustration and not limitation.

The merits of the invention are many. For example, the present invention improves control of the output power in the situations where there is an impedance mismatch at the output. Additionally, amplitude detector circuit 220 together with the current sensing protects power amplifier 102 from over voltage peaks.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example, and not limitation. It will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention as defined by the following claims. Thus the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.